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Summary

Seasonal gaseous N losses via denitrification and nitrous oxide (N_2O) emission from irrigated corn during a relatively dry 1991 season were 2.4 and 2.1 lb N/ac, respectively, which represented 1% of N applied as fertilizer or in irrigation water. Denitrification losses during the wetter 1992 season increased to 6.8 lb N/ac which represented 5% of N applied as fertilizer or in irrigation water. Relatively low gaseous N losses from denitrification and N_2O emissions from irrigated corn suggest little threat to atmospheric quality or N-use efficiency with good water and N management practices but also afford little hope for bioremediation of high-nitrate groundwater (32 ppm) under existing management. Better water and N management practices are the preferred and most efficient long-term solution to preventing and alleviating groundwater contamination.

Project Description

Problem: Economic constraints and concern for environmental quality during the final decade of this century challenge producers and researchers to develop agricultural production systems which use resources more efficiently and reduce nutrient losses to the environment. Inappropriate management of irrigation water and fertilizer N in irrigated corn has resulted in leaching of excess N from the rooting zone and contamination of groundwater with nitrate. The most appropriate approach to prevent groundwater pollution is to better manage irrigation water and fertilizer N for most efficient crop production (Schepers et al., 1991). However, a clearer understanding of the microbial conversion of plant available N to gaseous N forms is needed for most efficient use of soil and fertilizer N, for evaluation of agricultural management effects on atmospheric quality, and to determine the potential for microbial denitrification in remediating high-nitrate irrigation water and groundwater contamination. Nitrous oxide (N_2O) gas is produced by microorganisms during the oxygen-requiring nitrification of ammonium to nitrate and during denitrification, a process occurring in water-logged or soils with little oxygen, in which nitrate (NO_3^-) is reduced stepwise to NO_2, gaseous N_2O and N_2.

Objectives: The objectives of the research study reported here were to evaluate the potential for denitrification losses of NO_3-N and gaseous evolution of N_2O from soil in irrigated corn of the central Platte Valley and to evaluate if N_2O loss represented a potential threat to atmospheric quality.

Study methods: Gaseous emissions of N_2O and carbon dioxide (CO_2) from surface soil were measured from 80 acres of pivot-irrigated corn (E 1/2, NE 1/4, section 15, R13W, T9N) at the Management Systems Evaluation Area (MSEA) site near Shelton, Nebraska, during the 1991 and 1992 growing seasons. The soils at the experimental site are alluvial with the Hord silt loam (Cumulic Haplustoll) being the major soil series (84%) with some Hastings silt loam (10%) and Wood River silt loam (6%) soils as well. Finer-textured surface soil materials at this site are underlain by sand and gravel at depths of 1.5 to 4 feet. This situation results in a higher potential for nitrate leaching to groundwater, which contains 32 ppm NO_3-N, but also a greater potential for denitrifcation since the finer-textured surface soils must become saturated before percolate will move into the sand and gravel layers below. Sampling schedules for gas flux measurements were adjusted to enable most intensive sampling during periods when soils were wettest immediately after rainfall or irrigation and when N fertilizers were applied to soil directly or by fertigation.

Surface gas flux measurements were facilitated through installation of 6-inch diameter, 4-inch high PVC cylindrical rings which were installed to a depth of 3 inches, in between and within crop row areas, during the growing season in four replicate areas within the field. Gas flux measurements were taken 2 to 4 times each day by fitting the PVC cylinders with 0.5 gallon vented covers for 1-hour intervals during which time 0.8 in^3 gas samples were withdrawn in evacuated glass sampling tubes and transported to the laboratory for gas chromatographic analysis of CO_2 and N_2O. Measurements of denitrification were made through addition of lightly coated calcium carbide to soil around a separate set of cylinders which generated acetylene and effectively blocked nitrification and the reduction of N_2O to N_2 during denitrification. Thus, measurement of N_2O flux from carbide treated soils provided a direct estimate of soil denitrification. Soil samples were taken to a 3-inch depth from areas adjacent to cylinders before each sampling period and from within cylinders after sampling for determination of soil bulk density, water content, soil pH, and soil NH_4 and NO_3 levels. Soil temperatures at a 2-inch depth were monitored continuously during the sampling period using bi-metal thermometers. Details concerning the use of surface gas chambers, use of coated calcium carbide, and gas chromatographic analysis of CO_2 and N_2O are given by Aulakh et al. (1991) and Bronson et al. (1992).

Results

Denitrification and N_2O losses from soil in irrigated corn were low throughout most of the 1991 and 1992 growing seasons, ranging from 0.03 to 0.57 oz N/ac/d, when surface soils were generally dry and less than 60% of the soil pore space was water filled. Nitrous oxide was the major gaseous N product under these conditions, presumably a product of nitrification and not denitrification. The average monthly nitrous oxide emission from soil in the drier 1991 season ranged from 0.14 to 0.36 oz N/ac/d. This was much higher than that emitted in the wetter, 1992 season which was only 0.03 to 0.17 oz N/ac/d. Nitrous oxide was the major gaseous product lost from soil during the dry 1991 season but a minor component of gases lost during the wetter 1992 season. When soils were wetted by irrigation or rainfall to greater than 70% water-filled pore space (WFPS), denitrification losses ranged from 0.19 to 1.25 lb N/ac/d with N_2 comprising 80 to 100% of denitrification gases measured.

Rates of denitrification and N_2O production were similar for row and inter-row locations and differed significantly only when measurements were made shortly after planting, when the soil physical conditions and amounts of NO_3^- and NH_4^+ were different due to sidedress fertilizer applications and planting operations, or later in the growing season when soil density and water status varied between these row locations.

Table 1. Seasonal emissions of denitrification and nitrous oxide gases from irrigated corn at the MSEA center-pivot buffer area near Shelton, NE in 1991 and 1992.

	monthly losses, lb N/ac					Seasonal loss lb N/ac (% of N applied)
	April	May	June	July	August	
1991 - Dry year*						
Denitrification		0.00	0.45	0.83	1.11	2.39 (1.1%)†
Nitrous oxide		0.70	0.47	0.41	0.55	2.13 (1.0%)
1992 - Wet year*						
Denitrification	0.02	0.39	0.71	1.54	4.13	6.79 (5.0%)
Nitrous oxide	0.05	0.15	0.43	0.25	0.32	1.20 (0.9%)

* 1991- 3.0 in. growing season rainfall and 12.2 in. irrigation in < 1.0 in. increments.
1992- 12.4 in. growing season rainfall and 7.5 in. irrigation in < 1.0 in. increments.

† Values in parentheses represent loss as percentage of N applied in fertilizer and irrigation water; 209 and 137 lb N/ac applied in 1991 and 1992, respectively.

Soil respiration rates ranged from 4 to 29.4 and 0.9 to 33.8 lb CO_2-C/ac/d in 1991 and 1992, respectively, and varied with soil water status and soil temperature. Respiration rates of these magnitudes suggest that surface soil available carbon levels were adequate for microbial denitrification to occur. Also, microbial denitrification rates were synchronized with soil respiration rates over time. Significant denitrification losses from surface soil, however, only occurred over relatively short periods of time (1 to 2 days) when soils were wet to greater than 70% WFPS and surface soil NO_3^- levels exceeded 4.5 to 8.9 lb N/ac. The rapid decline of soil moisture after wetting was probably the major reason that significant denitrification losses only occurred during short periods of time.

Monthly gaseous N losses by denitrification increased during the corn growing season reaching a maximum in August (Table 1). Total seasonal N losses via denitrification and N_2O emission were estimated at 2.4 and 2.1 lb N/ac, respectively, during the relatively dry 1991 growing season. These losses represented about 1% of the N applied as fertilizer or in irrigation water. In the wetter 1992 growing season, denitrification losses increased to 6.8 lb N/ac which represented 5% of the N applied in fertilizer and irrigation water. Our findings agree with those of Bronson et al. (1992) that denitrification is not a major pathway for loss of fertilizer N in irrigated corn in semiarid and subhumid regions. And the monthly N_2O emission of 0.05 to 0.70 lb/ac observed in our study falls at the low end of the range of emissions from agricultural fields (0.06 to 3.64 lb/ac) as summarized by Williams et al. (1992).

Technology Transfer

Results of our two-year study with irrigated corn in Nebraska indicate that, under good irrigation and N management practices, gaseous N losses from denitrification and N_2O production pose little threat to atmosphere quality or N-use efficiency. However, such low emissions of gaseous N also afford little hope for bioremediation of high nitrate groundwater. Stimulation of microbial denitrification by adding ethanol to high nitrate irrigation water at this site can reduce nitrate levels by 25% within a few days (Weier et al., 1994). The practicality of this approach for biomediation of high nitrate groundwater, however, requires further evaluation.

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